



This is the submitted version of this journal article. Published as:

Wijndaele, Katrien and Healy, Genevieve N. and Dunstan, David W. and Barnett, Adrian G. and Salmon, Jo and Shaw, Jonathan E. and Zimmet, Paul Z. and Owen, Neville (2010) *Increased cardio-metabolic risk is associated with increased TV viewing time*. *Medicine & Science in Sports & Exercise*, 42(8). pp. 1511-1518.

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Increased Cardio-Metabolic Risk is Associated with Increased TV Viewing Time

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Running title: TV viewing time & cardiometabolic risk change

ABSTRACT

Purpose: Television viewing time, independent of leisure-time physical activity, has cross-sectional relationships with the metabolic syndrome and its individual components. We examined whether baseline and five-year changes in self-reported television viewing time are associated with changes in continuous biomarkers of cardio-metabolic risk (waist circumference, triglycerides, high density lipoprotein cholesterol, systolic and diastolic blood pressure, fasting plasma glucose; and a clustered cardio-metabolic risk score) in Australian adults.

Methods: AusDiab is a prospective, population-based cohort study with biological, behavioral, and demographic measures collected in 1999–2000 and 2004–2005. Non-institutionalized adults aged ≥ 25 years were measured at baseline (11,247; 55% of those completing an initial household interview); 6,400 took part in the five-year follow-up biomedical examination, and 3,846 met the inclusion criteria for this analysis. Multiple linear regression analysis was used and unstandardized *B* coefficients (95% CI) are provided.

Results: Baseline television viewing time (10 hours/week unit) was not significantly associated with change in any of the biomarkers of cardio-metabolic risk. Increases in television viewing time over five years (10 hours/week unit) were associated with increases in: waist circumference (cm) (men: 0.43 (0.08, 0.78), $P = 0.02$; women: 0.68 (0.30, 1.05), $P < 0.001$), diastolic blood pressure (mmHg) (women: 0.47 (0.02, 0.92), $P = 0.04$), and the clustered cardio-metabolic risk score (women: 0.03 (0.01, 0.05), $P = 0.007$). These associations were independent of baseline television viewing time and baseline and change in physical activity and other potential confounders.

Conclusion: These findings indicate that an increase in television viewing time is associated with adverse cardio-metabolic biomarker changes. Further prospective studies using

objective measures of several sedentary behaviors are required to confirm causality of the associations found.

Keywords: television, metabolic syndrome, waist circumference, blood pressure, triglycerides, HDL

INTRODUCTION

Paragraph Number 1 Sedentary behaviors, involving prolonged sitting, have become a prevalent feature of everyday living. Television (TV) viewing time is the most frequently reported leisure time sedentary behavior in adults from Australia, the United States of America (USA) and Great Britain (2,23,24). Cross-sectionally, TV viewing time, has been positively associated with the presence of the metabolic syndrome and its components using both categorical (5,8,11) and continuous (10,15,16,28) measurements. These associations were independent of leisure-time physical activity, and have also been found in physically active adults (15). Prospectively, TV viewing time and non-occupational sedentary behavior have been associated with self-reported weight change (6), obesity (18) and type 2 diabetes (17,18). However, to date, no prospective studies have examined the associations of TV viewing time with objectively-measured metabolic syndrome components in adults.

Paragraph Number 2 The Australian Diabetes, Obesity and Lifestyle Study (AusDiab) is a prospective population based cohort study of the aetiology of diabetes mellitus and related disorders, with baseline measurements taken in 1999–2000 and follow-up measurements taken 5 years later (2004–2005). This longitudinal study design allowed us to examine the effects of both baseline TV viewing and (simultaneous) change in TV viewing time on changes in cardio-metabolic risk. Based on previous cross-sectional results showing stronger associations in women compared to men (5,8,11,15,28) we studied these associations by gender.

METHODS

Study participants

Paragraph Number 3 The baseline AusDiab study was conducted during 1999-2000. As previously described in more detail a stratified cluster sampling method was used (9). Briefly, all eligible adults were recruited within 42 randomly selected urban and non-urban areas based on Census Collector Districts, 6 in each of the Australian States and in the Northern Territory of Australia. In total, 28,033 households were approached in the selected clusters. In the 19,215 households where contact was achieved, 2,086 households were considered ineligible. From the 17,129 eligible households, 5,178 households refused to participate in the household survey, the occupants of an additional 472 households were away from the residence during the survey period. As such, the number of eligible adults living in these 5,650 households could not be ascertained. From the 11,249 households that participated in the household interview, 20,347 adults (aged ≥ 25 years) completed the household interview, of whom 11,247 (55.3%) attended a testing site for the biomedical examination. A total of 8,798 (81.6%) took part in the 5-year follow-up survey (2004–2005), of which 6,400 participated in the biomedical examination; 137 attended an external pathology laboratory; and 2,261 completed a telephone questionnaire only. The present analyses used only those ($N = 4,953$) with complete data for: baseline and follow-up cardio-metabolic risk variables, TV viewing time, and confounding variables (physical activity time; education; employment status; income; cigarette smoking; alcohol; diet quality and energy intake (excluding participants ($N = 279$ out of 6,400) over- or under-reporting their dietary intake (29)); parental history of diabetes; baseline age, and medications for hypertension or dyslipidaemia at follow-up). Participants were excluded if they had clinically diagnosed diabetes ($N = 152$), self-reported angina ($N = 208$), stroke ($N = 74$), or myocardial infarction ($N = 155$) at baseline; or if they took medications for hypertension ($N = 709$) or dyslipidaemia at baseline ($N = 427$) (exclusion criteria were not mutually exclusive, so participants could be excluded based on more than one criterion). These exclusions were

made on the grounds that their condition might have affected their TV viewing time and their biomarkers of cardio-metabolic risk. The analysis included 3,846 adults (1,703 men and 2,143 women). The Ethics Committee of the International Diabetes Institute approved the AusDiab study design. Written informed consent was obtained from all participants.

Measures

Cardio-metabolic risk variables

Paragraph Number 4 Data collection procedures at baseline and follow-up were similar, as was follow-up time for all participants (approximately five years). After an overnight fast (minimum of 10 hours), participants attended a local survey centre, where an oral glucose tolerance test was performed using World Health Organization specifications (30). Fasting plasma glucose levels, fasting serum triglycerides, and high density lipoprotein (HDL) cholesterol levels were measured by enzymatic methods using an Olympus AU600 analyser (Olympus Optical, Co. Ltd, Tokyo, Japan) in 1999–2000, and the Roche Modular (Roche Modular, Roche Diagnostics, Indianapolis, USA) in 2004–2005: these methods were comparable across the two surveys (4). Trained personnel conducted duplicate waist circumference and resting blood pressure measurements. A more detailed description of these measurement protocols has previously been published (9). The cardio-metabolic risk variables were: waist circumference; triglycerides; HDL-cholesterol; systolic blood pressure; diastolic blood pressure; and fasting plasma glucose. A continuous clustered cardio-metabolic risk score based on these variables was constructed, similar to previous studies examining determinants of the metabolic syndrome/cardio-metabolic risk (e.g. 10). Briefly, after normalization (log 10), all cardio-metabolic variables (average blood pressure was used as an index for systolic and diastolic blood pressure) were standardized, i.e. z-scores were

computed ($z = ([\text{value} - \text{mean}]/\text{SD})$). For HDL cholesterol (protective for cardio-metabolic risk) the z-score was multiplied by -1. All z-scores were summed and the sum was divided by 5 to compile the cardio-metabolic risk score with units of SD. Means and SD of the representative 1999–2000 AusDiab baseline sample with complete cardio-metabolic data ($N = 11,029$) were used for standardization in both the 1999-2000 and the 2004-2005 data. The aim of using continuous outcome variables, both for the individual cardio-metabolic risk variables as the composite score was to maximize statistical power (25).

TV viewing time and physical activity time

Paragraph Number 5 Participants reported total time spent watching TV or videos in the previous week. This measure has been shown to provide a reliable (intra-class correlation = 0.82 (0.75, 0.87) and valid (criterion validity = 0.3) estimate of TV viewing time among adults (26). Using the Active Australia questionnaire, participants also reported their frequency and duration of moderate-to-vigorous intensity leisure-time physical activity during the previous week (1,3). This questionnaire has been shown to provide a reliable (intra-class correlation = 0.59 (0.52, 0.65)) and valid (criterion validity = 0.3) estimate of physical activity among adults (1,3). Changes in TV viewing time and physical activity were calculated as follow-up minus baseline. Change in TV viewing time was used both as a continuous and categorical predictor (> 1 hour/week = decrease; 0 ± 1 hour/week = no change; >1 hour/week = increase).

Potential confounding variables

Paragraph Number 6 The following demographic attributes were assessed using an interviewer-administered questionnaire: education (university or further education; yes/no), employment status (full time or part time job; yes/no), total household income (\geq

Aus\$1500/week; yes/no), cigarette smoking status (current heavy (≥ 20 cigarettes per day), current light (< 20 cigarettes per day), ex, non), alcohol intake (classified as non-drinker, light drinker, moderate to heavy drinker), and parental history of diabetes (yes/no). Dietary intake (usual eating habits over the past 12 months) was assessed using a self-administered validated food frequency questionnaire developed by the Anti-Cancer Council of Victoria (19), with total energy intake and a diet quality index score (Diet Quality Index-Revised, 0–100 with 100 representing high diet quality (22)) included in the analysis.

Paragraph Number 7 Change over the five years for employment status, income, smoking, and alcohol were categorized as decreased, no change, or increased; change for education was categorized as no change or increased.

Statistical Analysis

Paragraph Number 8 Multiple linear regression was used to examine the association of baseline and change in TV viewing with change in cardio-metabolic risk. Results provided are unstandardized *B* coefficients. For every regression model the following five checks were made: 1) standardized residuals and Cook's distance for outliers and influential cases; 2) normality of standardized residuals; 3) homoscedasticity of standardized residuals; 4) the Durbin-Watson statistic to test the independence of residuals; 5) the variance inflation factor to test multicollinearity. Analyses were conducted using SPSS 14.0 (SPSS, Inc., Chicago, IL, USA) and STATA 10.0 (StataCorp. LP, College Station, TX, USA). Statistical significance was set at $P < 0.05$.

Regression models for baseline TV viewing time (hours/week)

Paragraph Number 9 Change in the clustered cardio-metabolic risk score and the individual cardio-metabolic risk variables was regressed against: baseline TV viewing time; baseline age and cardio-metabolic risk variable under study; baseline education, employment status, income, cigarette smoking, alcohol, diet quality and energy intake, and parental history of diabetes; and hypertension or lipid medication use at follow-up (Model A). Adding baseline physical activity time gave the effect of baseline TV viewing time independent of physical activity (Model B). Adding baseline waist circumference examined if central obesity attenuated the association of baseline TV viewing time with change in the following cardio-metabolic risk variables: triglycerides, HDL-cholesterol, systolic and diastolic blood pressure and fasting plasma glucose (Model C). In the regression models for baseline TV viewing, TV viewing precedes change in cardio-metabolic risk, which allows inference about the causality of any effects found.

Regression models for change in TV viewing time (hours/week)

Paragraph Number 10 Change in the clustered cardio-metabolic risk score and the individual cardio-metabolic risk variables was regressed against: change in TV viewing time; baseline TV viewing time; baseline age and cardio-metabolic risk; baseline and change in education, employment status, income, cigarette smoking, alcohol, diet quality and energy intake; any parental history of diabetes at follow-up; and follow-up hypertension or lipid medication use (Model A). Adding baseline and change in physical activity gave the effect of a change in TV viewing time, independent of physical activity (Model B). Additionally adjusting for baseline and change in waist circumference examined if central obesity attenuated the association of change in TV viewing time with change in the following cardio-metabolic risk variables: triglycerides, HDL-cholesterol, systolic and diastolic blood pressure and fasting plasma glucose (Model C).

Paragraph Number 11 In the multiple linear regression models including change in TV viewing time as a categorical variable, participants showing no change (0 ± 1 hour/week) and participants increasing (> 1 hour/week increase) their TV viewing time were compared to the reference group of participants decreasing (> 1 hour/week decrease) their TV viewing time. Also, a linear trend for more unfavorable changes in cardio-metabolic risk across the three TV viewing-time categories was examined.

Paragraph Number 12 In the regression models for change in TV viewing, the changes for TV viewing and cardio-metabolic risk occur during the same period of 5 years, which does not allow inference about the causality of any effects found.

Data imputation and sensitivity analysis

Paragraph Number 13 As a sensitivity analysis of the effect of missing data, we imputed the missing data for all participants of the baseline AusDiab measurement phase ($N = 11,247$) and re-ran the regression models for both baseline and change in TV viewing on 8,078 subjects after applying the original exclusion criteria (20). We created 10 datasets with stochastically imputed values and then combined the parameter estimates using PROC MIANALYZE in SAS 9.1 (SAS Institute Inc, Cary, NC, USA). We imputed values for the continuous variables by assuming they had a multivariate normal distribution. We estimated the variance–covariance matrix using WinBUGS 1.4 (MRC Biostatistics Unit, Cambridge, UK), and also used this software to impute values using a Markov chain Monte Carlo simulation. For missing variables that were binary or ordinal, we used regression models to estimate the missing values. These models and imputed values were also estimated using WinBUGS.

RESULTS

Descriptive characteristics of the sample

Paragraph Number 14 Demographic characteristics of participants and changes in TV viewing time, physical activity and cardio-metabolic risk are shown in Tables 1 and 2. TV viewing time increased by approximately 1 hour/week over the five years in men and women (Table 2).

Paragraph Number 15 A comparison between participants included in the current analyses (Table 1) and those only taking part in the baseline 1999–2000 AusDiab survey (without any further exclusions) showed that men and women in the current analyses watched less TV at baseline, and that women in the current analyses were more physically active at baseline. They also showed a more-favorable profile for all of the cardio-metabolic risk variables compared to those who took part in the baseline 1999–2000 study phase only, except for diastolic blood pressure in men, which was similar (results not shown).

INSERT TABLES 1 AND 2 ABOUT HERE

Regression models for baseline TV viewing time

Paragraph Number 16 Results for the associations of baseline TV viewing time and continuous change in TV viewing time with change in the cardio-metabolic risk variables are presented in Table 3. All regression coefficients (95% CI) in this table are expressed using a unit of 10 hours/week for TV viewing time. No significant associations were found between

baseline TV viewing time and changes in any of the cardio-metabolic risk variables (Table 3).

Regression models for change in TV viewing time

Continuous TV viewing time

Paragraph Number 17 Increasing TV viewing time was associated with increasing waist circumference in men and women, and additionally with increasing clustered cardio-metabolic risk and diastolic blood pressure in women (Table 3, Model A). These associations were unchanged following additional adjustment for physical activity (Model B). Every 10-hour increase in TV viewing time was, for example, associated with an average 0.43 cm increase in waist circumference in men and an average 0.68 cm increase in women. The effect of change in TV viewing time on diastolic blood pressure in women was attenuated by additional adjustment for waist circumference (Model C). No significant associations were found between change in TV viewing time and change in triglycerides, HDL-cholesterol, systolic blood pressure or fasting plasma glucose.

INSERT TABLE 3 ABOUT HERE

Categorical TV viewing time

Paragraph Number 18 Figure 1 shows the cardio-metabolic risk factors that were altered with a change in TV viewing time as a categorical variable (decreased (reference group): >1 hour/week less; same: 0 ± 1 hour/week; increased: >1 hour/week more TV viewing time). Results are shown after adjustment for physical activity (Model B). Compared to women who decreased their TV viewing time (reference group), women who increased their TV

viewing time significantly increased their clustered cardio-metabolic risk score, waist circumference and triglycerides. For example, women increasing their TV viewing time showed an increase in waist circumference which was on average 1.3 cm higher than the increase in waist circumference seen in women decreasing their TV viewing time. The unfavorable changes in clustered cardio-metabolic risk, waist circumference and triglycerides were also evident as a trend across the three TV viewing-time categories in women. Compared to men who decreased their TV viewing time, a significant decrease in HDL-cholesterol was found in men who did not change their TV viewing time.

INSERT FIGURE 1 ABOUT HERE

Sensitivity analysis

Paragraph Number 19 After imputing missing data the coefficients were similar or stronger and more statistically significant compared with the results shown in Table 3 (results not shown).

DISCUSSION

Paragraph Number 20 In this prospective population-based cohort of Australian adults, baseline TV viewing time was not associated with subsequent five-year change in cardio-metabolic risk. However, change in TV viewing time over a five-year period was significantly positively associated with changes in waist circumference in men and women, and additionally with clustered cardio-metabolic risk and diastolic blood pressure in women. These associations were largely independent of several potential confounding factors,

including physical activity and diet. The findings for change in TV viewing time are consistent with those of cross-sectional studies that have shown significant associations of sedentary time with continuous measures of these individual cardio-metabolic risk variables and clustered cardio-metabolic risk (15,16,28). They suggest that significant beneficial cardio-metabolic effects could result from reducing time spent in TV viewing time or vice versa.

Paragraph Number 21 This is the first prospective study to examine the association between TV viewing and objectively assessed biomarkers of cardio-metabolic risk. Additional strengths include the large, population-based sample covering a wide age range with similar numbers of men and women. We were also able to adjust for a variety of relevant confounding variables, including diet and physical activity. Other key strengths are the use of continuous outcome measures for the individual cardio-metabolic risk variables and clustered cardio-metabolic risk (25).

Paragraph Number 22 However, our study is not without limitations. While the outcome measures are objectively assessed biological attributes, our findings rely on self-report indices of TV viewing time and other behavioral variables. Differences in measurement error between these self-reported behavioral variables might bias results. Measurement error in explanatory variables biases associations towards the null because of the regression dilution bias, and the greater the measurement error the greater the bias towards the null (21). Therefore, the associations shown here may actually be underestimates of the true association. Some misclassification might also exist, for those participants who did spend some of their TV viewing time in a physically active way. However, we aimed to minimize this type of misclassification by adding the following phrase to the question estimating time

spent watching TV or videos: “This is when it was the main activity you were doing; for example you would not include time when the television was switched on and you were preparing a meal.” Further, residual confounding might exist, especially for the categorical predictors. We had no information on parental history of cardiovascular disease, but probably partially accounted for its confounding effect by adjusting for medication for dyslipidaemia and hypertension at follow-up, and excluding participants with self-reported angina, stroke, or myocardial infarction or taking medications for hypertension or dyslipidaemia at baseline. Similarly, we have not adjusted for prevalent musculoskeletal problems, possibly confounding the associations examined, but probably partially accounted for this by adjusting for physical activity levels. Also, although TV viewing is the most prevalent leisure-time sedentary behavior, and a marker of overall leisure-time sedentary behavior in women (27) we have not examined total sedentary behavior. Thus, caution is needed in generalizing these results to other types of sedentary behavior (e.g., workplace sitting). Also, as TV viewing time might be associated with these other types of sedentary behaviour (27), they may be another source of residual confounding. The sensitivity analysis, including 8,078 participants (after applying the original exclusion criteria), showed similar or stronger associations, which indicates that any bias caused by missing data is likely to mean that we have underestimated, rather than overestimated, the true association. Further, the exclusion criteria for this analysis probably contributed to a disproportionately healthy cohort, shown by the difference in baseline characteristics comparing the current study group with those only participating in the baseline 1999–2000 survey without further exclusion. Therefore, the exclusion criteria might also have resulted in an underestimation of the true association. Additionally, change in TV viewing time did not precede change in cardio-metabolic risk, so inference about the causality of the associations found cannot be made. However, in contrast to previous cross-sectional studies that estimated the effect of TV

viewing time on metabolic risk between-subjects, the change models applied here estimated the effect within-subjects. Within-subject effect estimates are less prone to unmeasured time-independent confounders (e.g., genetic factors) as each subject acts as his or her own control. Between-subject estimates rely on the strong assumption that changes in risk observed between groups of individuals with low and high levels of exposure would be repeated (on average) in an individual, if that person changed their exposure from low to high.

Paragraph Number 23 Several reasons might account for the differences in results found for baseline and change in TV viewing time. First, baseline TV viewing time is a proxy measure of long-term TV viewing behavior preceding the 5-year change in cardio-metabolic risk. However, almost 80% of participants in this study either increased or decreased their TV viewing time over 5 years, which indicates that this is not a stable behaviour (with slightly more participants increasing their TV viewing time, which might be an age-related effect). Second, measurement error introduced through, for example, underreporting by overweight/obese subjects, is smaller for change in TV viewing compared to baseline TV viewing. This is because these individuals will underreport in a similar way at two different time points, and a difference between two time points will have lower measurement error than one single measurement (if their weight status does not change substantially from baseline to follow-up). Third, it is still unknown whether the effects of TV viewing on cardio-metabolic risk are predominantly short term (less than five years) or long term (longer than five years). Predominantly short term effects might explain why no associations were found for baseline TV viewing time. Finally, as change in TV viewing time, in all covariates, and in cardio-metabolic risk occurred concurrently during the same period, we cannot be sure about the direction of causality. However, we did adjust for baseline cardio-metabolic risk, which supports unidirectional causality of the findings.

Paragraph Number 24 The significant positive association between change in TV viewing time and change in waist circumference and clustered cardio-metabolic risk may reflect changes in energy intake, particularly that induced through snacking, while watching TV (7). Although we adjusted for overall diet quality and energy intake, the measurement tool did not specifically measure snacking. TV viewing time may be displacing physical activity, particularly light-intensity activity, which has been associated with lower waist circumference and overall cardio-metabolic risk (16). Previous research has reported that sedentary time and light-intensity physical activity time are highly correlated (whereas the correlation with moderate-to-vigorous physical activity time is weak) (16). Thus, the increases in risk observed here with increased TV viewing may be due to the reduction in energy expenditure resulting from reduced time spent in light-intensity activity.

Paragraph Number 25 For TV viewing time as a categorical variable, significant associations were observed with triglycerides and HDL-cholesterol. Cross-sectionally, significant associations have been reported between objectively-measured sedentary time and triglycerides (16) and borderline significant associations ($P < 0.1$) between sedentary time and HDL-cholesterol (10). Studies in animals have shown sensitivity of skeletal muscle lipoprotein lipase to be suppressed by muscle inactivity, resulting in a rapid local impairment in triglyceride and HDL-cholesterol metabolism (12). This process is specific to sedentary behaviors (such as TV viewing), which are characterized by absence of whole body movement and muscle contractions (12). Consistent with these experimental studies, research in free-living adults has reported that regular interruptions to sedentary time were beneficially associated with triglycerides (14).

Paragraph Number 26 The associations for change in TV viewing time appear stronger for women than for men, but interaction effects were non-significant (results not shown). At baseline, men showed more-unfavorable values compared to women for several exposures (poorer diet quality, higher energy intake, more heavy smokers, and more moderate-to-heavy drinkers) and all outcomes. This might suggest a ceiling effect in men, through which these variables only have limited opportunity to become worse, possibly explaining the results found. Future prospective studies should further examine whether gender differences exist in the effect of TV viewing on cardio-metabolic risk. Further, prospective studies in different age groups are necessary to infer whether potential effects on these cardio-metabolic risk factors are age-specific. Within our study, we could not find evidence for a moderation effect by baseline age (≤ 45 versus > 45 years of age) (results not shown). One longitudinal birth cohort study (13) has shown a significant association between child and adolescent TV viewing and higher serum cholesterol at age 26 years.

Paragraph Number 27 This study reported that five-year increases in TV viewing time were significantly associated with unfavorable five-year changes in clustered cardio-metabolic risk, waist circumference and diastolic blood pressure, largely independent of physical activity and other potential confounding variables. Although further evidence is needed to confirm the causal nature of these associations, these findings suggest that irrespective of person's physical activity level an increase in their TV viewing time may have negative cardio-metabolic health consequences. This supports the need to consider sedentary behavior guidelines, complementary to the established public health guidelines that exist for physical activity in adults. Interventions aiming to reduce cardio-metabolic risk may need to focus on reducing TV viewing time in addition to adhering to the physical activity health guidelines.

ACKNOWLEDGEMENTS

Wijndaele and Owen are supported by a Queensland Health Core Research Infrastructure Grant and National Health and Medical Research Council (NHMRC) Program Grant funding (#301200). Wijndaele is also supported by the Medical Research Council. Healy is supported by a NHMRC (#569861) and National Heart Foundation of Australia (PH 08B 3905) Postdoctoral Fellowship. Dunstan is supported by a Victorian Health Promotion Foundation Public Health Research Fellowship. Salmon is supported by a National Heart Foundation of Australia and Sanofi-Aventis Career Development Award. The AusDiab study is supported by an NHMRC project grant (#233200). For further acknowledgements regarding AusDiab, please refer to Dunstan et al. (8).

CONFLICT OF INTEREST

None of the authors have any conflict of interest. The results of the present study do not constitute endorsement by ACSM.

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FIGURE 1 CAPTION

Figure 1. Cardio-metabolic risk change comparing participants decreasing, staying the same or increasing their TV viewing time.

FIGURE 1 LEGEND

Participants decreasing their TV viewing time: reference group: >1 hour/week less; those staying the same: 0 ± 1 hour/week; those increasing their TV viewing time: >1 hour/week more. Change is follow-up minus baseline. Data are adjusted means (SE). Models are adjusted for baseline TV viewing time; baseline age and cardio-metabolic risk variable under study; baseline and change in education, employment status, income, cigarette smoking, alcohol, diet quality, energy intake and physical activity; follow-up parental history of diabetes; and follow-up hypertension or lipid medication use (only for clustered cardio-metabolic risk, triglycerides and HDL-cholesterol).

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$.